1-1-1974

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Introduction

The fluctuating margin of the Late Wisconsin Laurentide Ice Sheet in Maine retreated approximately parallel to the coast leaving a belt of submarine end moraines (Borns, 1966, 1973). This recession was accompanied by a marine transgression of the coastal region that extended into the river valleys of central Maine (Goldthwait, 1949). Glaciomarine sediments up to approximately 150 feet thick were deposited in the coastal region. Inland of the end moraine belt central Maine is characterized by ground moraine, eskers up to 80 miles long extending to the southeast-facing slopes of the northeast-southwest-trending highlands of the state (Leavitt and Perkins, 1936) and glaciomarine sediments in the major river valleys.

The glacial geology of eastern coastal Maine is characterized by a northeast-southwest-trending 25 mile wide complex composed of hundreds of end moraines and associated features (Leavitt and Perkins, 1935; Borns 1966, 1967, 1973) deposited along a fluctuating glacier margin as it retreated northwest from a position on the continental shelf. Most, and perhaps all, of these moraines were deposited below the sea level that prevailed at that time. Within the end-moraine complex as many as 20 local marginal fluctuations are recognized.

End-Moraine Complex

The end-moraine complex is characterized by hundreds of end moraines, but also includes ice-marginal kames and marine deltas and interlobate deposits (fig. 1).

Two types of end moraines are recognized; a large, stratified and relatively continuous type in contrast to the mor numerous, small non-stratified and discontinuous "washboard" type. The large moraines are often up to 60 feet high, 300 feet wide with segments continuous for up to 10 miles in length. Internally these are composed predominately of stratified sand and gravel with minor interbeds of compact till and fossiliferous marine silts. Commonly these deposits have been deformed by ice push from their proximal sides which, coupled with the cross-cutting lobate map-pattern of the moraines, indicates that the moraines formed along the margin of an internally active ice sheet. These moraines are very similar in composition and origin to the Ra and Central Swedish moraines of Scandanavia.

The majority of the smaller and more numerous type of moraine seldom exceed 10 feet in height, 30 feet in width and 0.5 mile in length. Commonly

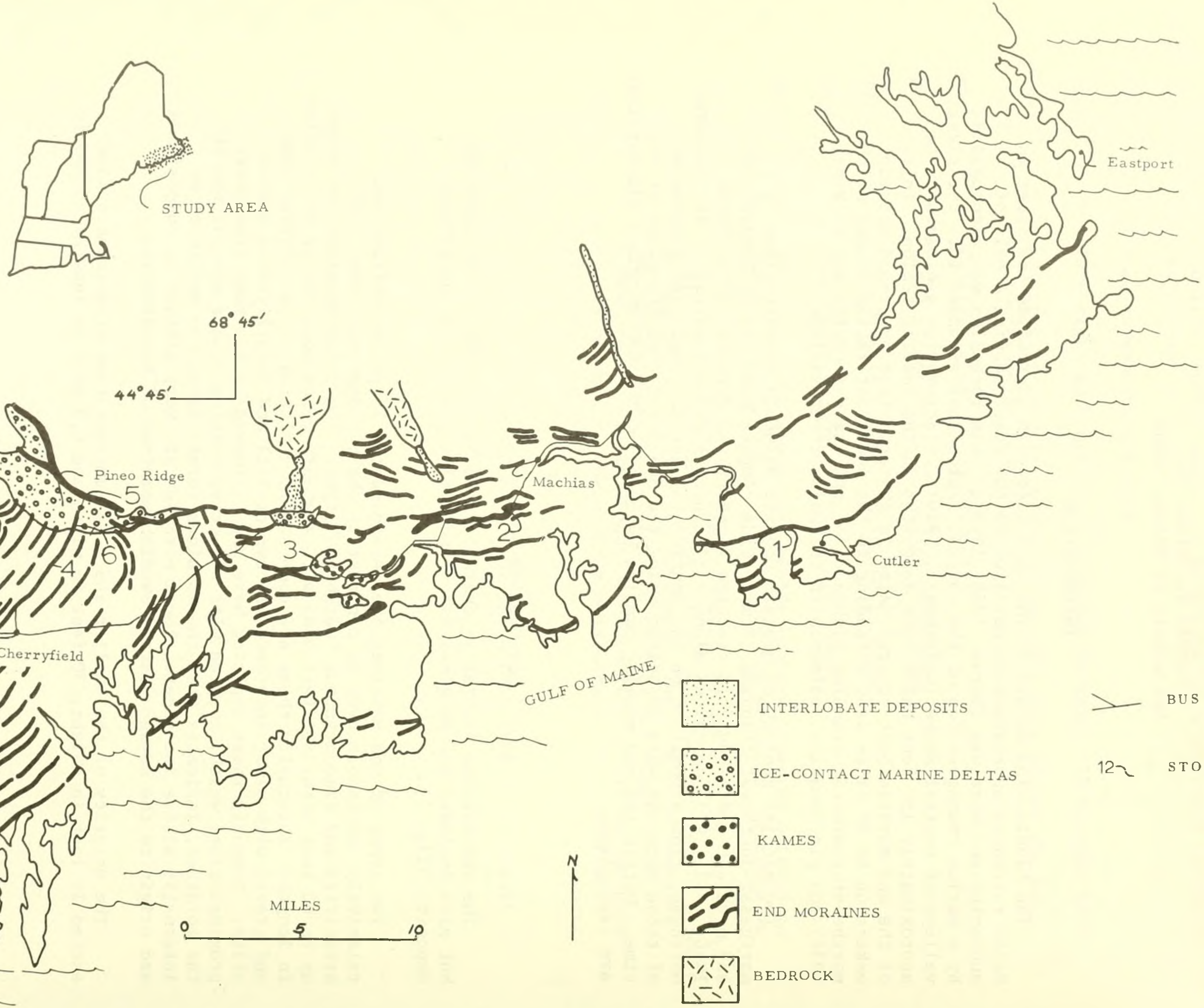

Figure 1. Generalized map showing the glacial geology of eastern Maine.

they occur in clusters of up to 50 parallel curved and evenly spaced moraines and hence the name "washboard" moraines. Nearly all of these moraines are composed of compact till.

The spatial and stratigraphic relationships of both types of moraines indicate that the larger stratified moraines formed during local readvances of the ice margin and that the smaller "washboard" moraines formed during the subsequent recessions. All the moraines found are below the upper marine limit and most probably formed below sea level. The processes responsible for the differences in the characteristics of these two types of moraines are now being studied.

The large volume of stratified drift within the large moraines and their wide distribution indicate that extensive melting of the ice sheet was prevalent and that while generally meltwater was discharging all along the ice margin local drainage concentrated large deposits of stratified drift as kames or marine deltas at the margin formed.

Marine Transgression

The recession of the ice sheet in the coastal and central sections of Maine was contemporaneous with a marine transgression. Evidence of both submergence and emergence is generally documented by the fossilferous silty clay deposits of the region which form a discontinuous cover partially filling the valleys and lapping up on the highlands to the altitude of the maximum postglacial marine submergence (Goldthwait, 1949). The marine sediment, named the Presumpscot Formation (Bloom, 1960), was deposited in the proximity of the receeding ice margin as indicated by the ice-marginal deltas, inter-tongued marine sediments within the end moraines, the abundance of ice-rafted erratics, and by the cold water marine fauna within the sediment.

Pineo Ridge Readvance

The glacier recession that produced the coastal moraine complex was interrupted by an extensive readvance in eastern Maine that terminated in the sea at Pineo Ridge Moraine approximately 12,800 to 12,600 years ago (Borns, 1973). Reconaissance of the distribution of deposits and of ice movement indicators demonstrate that the margin receded a minimum of 50 miles before readvancing to the position of Pineo Ridge Moraine.

Chronology

The Late Wisconsin terminal position of the Laurentide Ice Sheet east of the Hudson River is marked by the Ronkonkoma-Vineyard-Nantucket moraine line (Schafer, 1961; Kaye 1964; Schafer and Hartshorn, 1965) and probably by the distribution of coarse gravel on the continental shelf to the east (Schlee and Pratt, 1970).

The ice sheet reached its maximum extent in southeastern New England at least sometime after 20,000 years B.P. (Schafer and Hartshorn, 1965) and was probably still in this position on Marthas Vinyard, Massachusetts as late as 15,300 years B.P. (Kay 1964). By approximately 13,500 years B.P. the margin of the ice sheet had receded to the present position of the Maine coast and at least by 12,300 years B.P. the entire coastal moraine complex had been deposited (Stuiver and Borns, unpub. data).

Approximately 30 C^{14} dates on marine organisms contained in the emerged glaciomarine sediments and on the oldest organic sediments in lakes below the upper marine limit closely bracket the time of the marine submergence and therefore the formation of end moraines of the coastal region between 13,500 and 12,300 years B.P. (Borns, 1967; Stuiver and Borns, 1967; Stuiver and Borns, unpub. data).

Correlation

The deglaciation of coastal Maine and probably New Brunswick was well underway by 13,500 years B.P. This recession was interrupted by a readvance in the St. John River lowland of Maine and New Brunswick that terminated at the Pineo Ridge Moraine in eastern Maine about 12,700 years B.P.

In the Great Lakes region the Cary-Port Huron recession is documented by an intertill bryophyte bed in northern Michigan dated at 12,500 - 13,000 years B.P. and by low-level Lake Arkona in the Erie basin. The Port Huron readvance is recorded by till overlying the bryophyte bed, by the transition from Lake Arkona to Lake Whittlesey about 13,000 years B.P., and by the Port Huron Moraine.

The events in coastal Maine and the Great Lakes region are similar within the limits of C^{14} dates and stratigraphic control. Therefore Borns and Denton (1972) have suggested that the concept of the Cary-Port Huron recession and subsequent Port Huron readvance can be extended to eastern North America.

Rapid deglaciation of much of eastern North America and the Great Lakes area 13,500-13,000 years B.P. was followed by wide-spread readvance 13,000-12,500 years B.P. that culminated at the Port Huron Moraine and the Pineo Ridge Moraine. If this correlation proves to be correct, the widespread nature nature of these events would suggest an important climatic reversal that affected a large segment of the southern margin of the Laurentide Ice Sheet.

Acknowledgment

This research was supported by National Science Foundation grants, Ga-2823, Ga-404, Ga-1563.

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Mileage

0 Assembly point for trip is in the parking area on the southside of causeway Rt. 1, one mile east of Machias center at 8:00 a.m. Drive east on Rt. 1 to East Machias.

2.9 Turn right. Follow Rt. 191 to North Cutler.

12.4 Stop 1. Park along highway. This E-W trending end moraine is one of the most prominent and accessible in the area and is traceable as a nearly continuous ridge for at least 35 km (Fig. 1). In their study of the glacial geology of Maine, Leavitt and Perkins (1935) reported briefly on this region and on this particular end moraine that they named the Pond Ridge Moraine. Their description of the end moraine is as follows:

> "The frontal deposits (in Maine in general, and at Cutler in particular) take on the form of a rather smooth or hummocky ridge, with an ice-contact slope on the proximal side and a gently sloping wash plain on the distal side. Goldthwait has termed frontal deposits of this type moraine banks." Moraine banks were visualized as having formed along an ice margin which was standing in the sea.

The orientation of the shoreline exposure at this location provides an unusual opportunity to study the internal characteristics of the moraine. In general adequate exposures of the moraines of this region are notably absent.

The moraine rests (?) upon fossiliferous marine clay and is composed of interbedded sands and gravels, tills and fossiliferous marine, silty clay. Radiocarbon ages on the contained fossils date the formation of the moraine at approximately 13,500 years B.P. (Stuiver and Borns, unpub. data).

21.9 Return to Rt. 1 in East Machias via Rt. 191 and turn right. Pass through Machias center.

25.1 Stop 2. Turn right into Whitney's gravel pit.

This borrow pit has been excavated in a large moraine (Fig. 1) and exposes its internal character roughly from the moraine crest to its proximal side. The moraine is composed of stratified sand and gravel with interbeds of compact till. Deformation structures show translation from the proximal to the distal side of the moraine and probably reflect the thrusting of the ice sheet. No marine sediments have been recognized in this pit. However, at other locations marine silts are interfingered with the coarser sediments on the distal side of this moraine.

Return to Rt. 1 and turn right (west) and follow the crest of this moraine for approximately 3.5 miles.

34.0 Stop 3. Lunch on Carr Hill.

The several borrow pits on this hill expose stratified sand and gravel in long foreset beds dipping to the south. No till or marine silt are exposed. This hill, located along a moraine line (Fig. 1), is interpreted as an ice marginal kame probably formed in the sea. The top of the hill at altitude of 217 feet is below the upper marine limit of approximately 300 feet in the coastal zone. Continue west on Rt. 1.

48.2 Turn right on Rt. 191 in the center of Cherryfield (the Blueberry Capitol of the World).

49.5 Turn right on Ridge Road.
The road roughly follows the crest of a N.E.-S.W. trending end moraine whose proximal side faces northwest (to your left).

51.7 Stop 4. Park along the roadside. At this location the end moraine, along whose crest we've been driving, wraps around the NW side of the bedrock knob. From this location there is a panoramic view of a few of the hundreds of small, boulder strewn, recessional end moraines located to the northwest. These moraines are often clustered and may be called "washboard" moraines.

These moraines were formed along the margin of an ice lobe retreating to the northwest from a position southeast of Stop 4 (Fig. 1).

On the skyline to the north you can see the front slope of the Pineo Ridge ice-marginal delta extending for at least 6 miles east to west. The delta was prograded over the northern ends of many of the small moraines just discussed and therefore is younger than these moraines.

Continue northward for approximatly 3 miles on or parallel to this moraine and then drive up the partially disected front slope of Pineo Ridge delta. Note the fine sand in the road cuts. Low areas to the south of here are veneered with marine silt and clay of the Presumpscot Formation (Bloom 1960).

54.2 Top of delta. Bear left and drive north across the delta surface to the ice-contact proximal slope.

Note the myriad of abandoned distributary meltwater channels, the coarsening of the sediments toward the north, and the change from a smooth to a [kettled] surface as the proximal side is approached.

55.9 Stop 5. We are standing on the Pineo Ridge Moraine. This end moraine curves northwest from here where it ends (?) in approximately 10 miles. To the east it has been mapped, discontinuously

for approximately 60 miles and at Lubec, Maine passes into Passamaquoddy Bay. This moraine has not yet been recognized in New Brunswick. Return south on same road.

57.7 Turn left and drive east along the distal edge of the delta.

59.4 Stop 6. We are standing at the east end of the U.S. Coast and Geodetic Survey Base Line upon which most mapping control in Maine is based. This line was surveyed in the first half of the 19th century and Jefferson Davis, later to become president of the Confederate States of America, participated in the survey.

As you look around at this and other locations you will notice the vast ares of blueberry cultivation. In 1958 this area of Maine produced 85% of the world's commercial berries. Of the 100,000 acres of land in Maine presently under blueberry cultivation, 50,000 are in this immediate area. We can thank the Laurentide Ice Sheet for this!

This is the eastern end of the Pineo Ridge delta and we're standing near the outer edge of its depositional surface at an altitude of 260 feet. As the constructional phase of the delta came to a close the delta emerged about 20 feet above sea level and the sea eroded the prominent bench and cliff before us. This *nickpoint at an altitude of 240 feet is present along approximately 90% of the length of the delta front. Prominent nickpoints at this altitude have been recognized at various other locations in the coastal region from Lubec to Waldoboro, Maine, a distance of approximatley 180 miles. The local collapse of the 240 foot-high shoreline into kettle holes and the presence of meltwater stream channels graded to a sea level lower than the altitude of 240 feet on this delta indicate the presence of glacial ice in the area while emergence was in progress.

After this prominent nickpoint was formed the delta emerged relatively more rapidly and several lower, less conspicuous nickpoints were developed at lower altitudes. Relative sea level lowered to approximately -180 feet by 10,000 years B.P. and has subsequently risen to its present position.

* ("nickpoint" as used here refers to the point where the wave-cut cliff joins the wave-cut platform. It represents a former sea level.)

Drive east on the same road. Note that you are driving on the Pineo Ridge Moraine and that the delta is no longer present.

61.9 Turn right on paved road.

62.2 Stop 7. Park along the roadside.

At this location the E-W trending Pineo Ridge Moraine, constructed by ice readvancing from just east of north, crosscuts the N-S trending moraines constructed by ice that had advanced from and was receding toward the northwest.

Drive south to Rt. 1, turn left and continue to Ellsworth, Bangor and Orono. This will take approximately 1 1/2 hours.